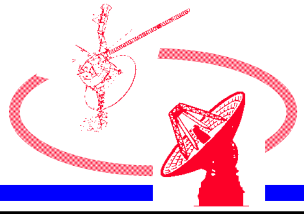
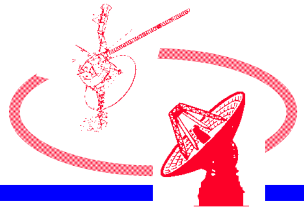


Characterization of the Random-Access-Windowing CCD Camera for Optical Comm ATP Subsystem

W. Farr, B. Liu, S. Monacos

Jet Propulsion Laboratory
California Institute of Technology

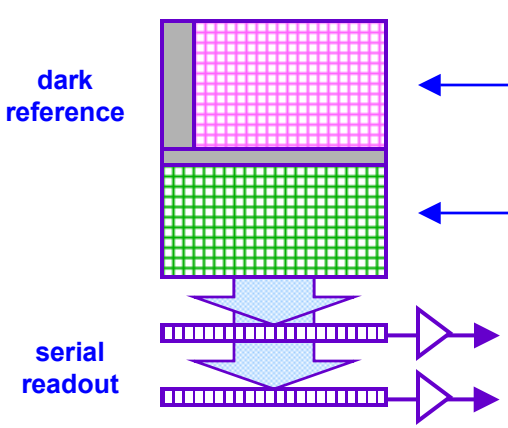
Outline



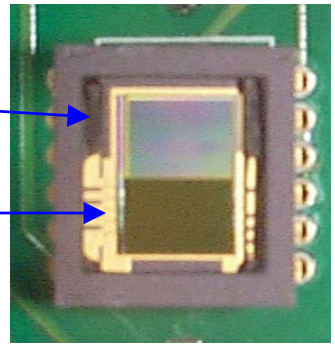
- Camera description
- Characterization test goals
- Imaging characteristics
- Flat field testing
- ^{55}Fe testing
- Conclusions

Random Access Windowing CCD Camera

- FPGA based CCD camera to implement dual ROI windowing
  - specific application to JPL ATP designs
  - dual ROI for laser beacon and transmit laser reference
  - required to support > 2 KHz frame rates
- Based upon Texas Instrument TC237 CCD
  - 680 x 500 resolution, 7.4μm x 7.4μm pixel size
  - 25 MHz rated parallel and serial transfer clocks
  - dual serial readout registers
  - frontside, frame-transfer device
  - 30K e- typical full well
- CCD interface circuitry using TI interface chips
  - TMC57253 level translator/clock driver
  - TLV987 CDS signal processor with 36 dB PGA and 10-bit ADC



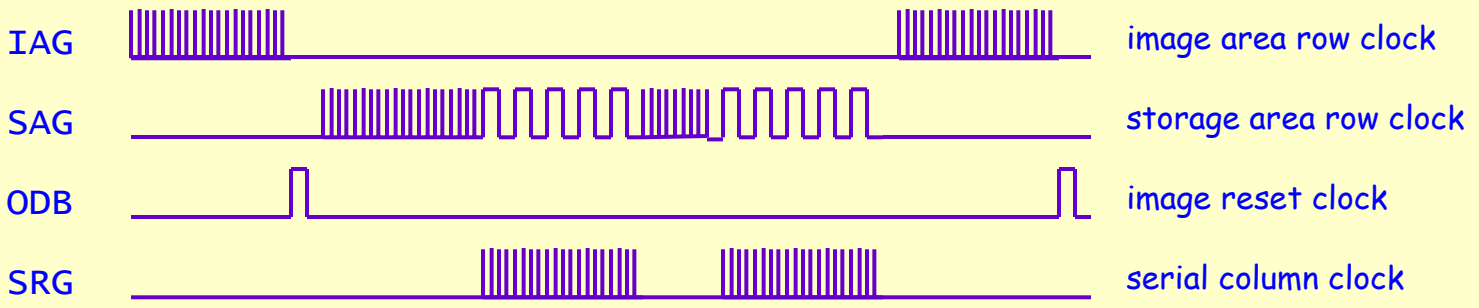
TC237 Architecture



TC237 Chip
(window removed)

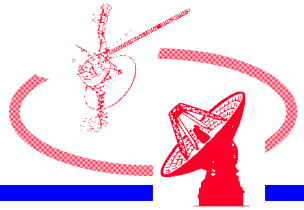
ROI Clocking

- variable rate clocking to maximize frame transfer rate



a) Transfer image area to readout area
b) Shift and discard rows to leading row of ROI
c) Shift and discard columns to leading column of ROI
d) Readout ROI pixels
e) Repeat by discarding intermediate data to next ROI

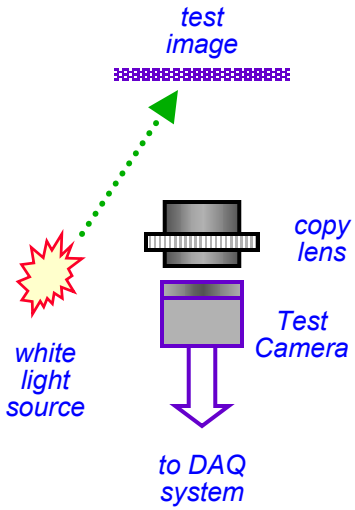
Characterization Goals



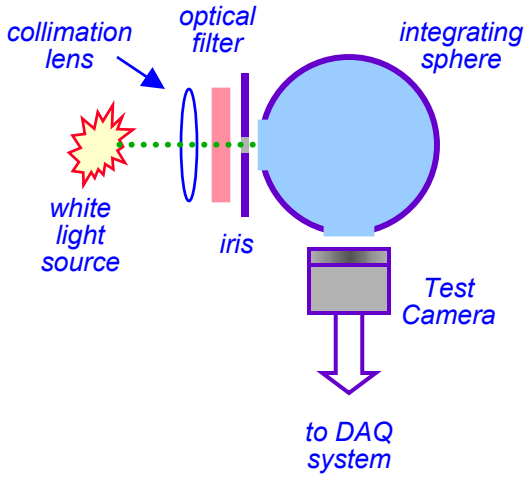
- How does the FPGA based design function as a “camera” ?
- General image quality
  - single vs. dual serial channel readout
- Dark response
  - ‘hot’ pixels
- Flat field spatial response
  - spatial gain uniformity
  - photoelectric response from gain variance
  - full well saturation levels
- ^{55}Fe radiation response
  - photoelectric response from single pixel event histograms

Experimental Setups

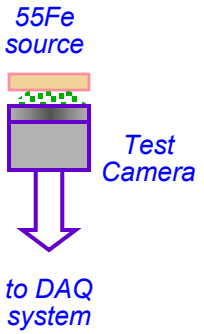
Imaging



Flat Field

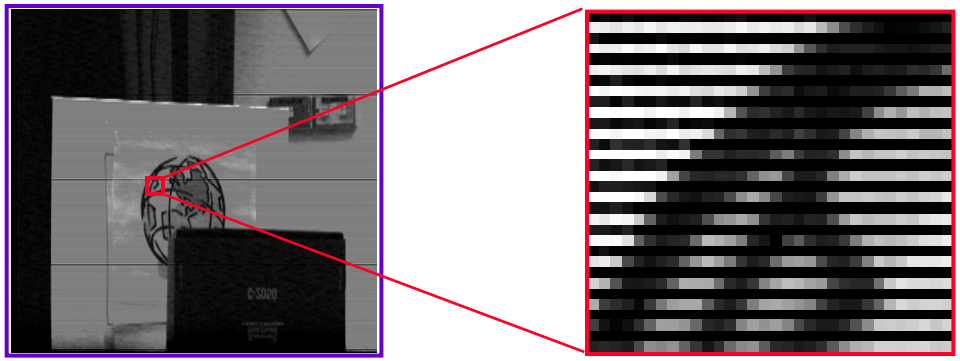


Ionizing Radiation

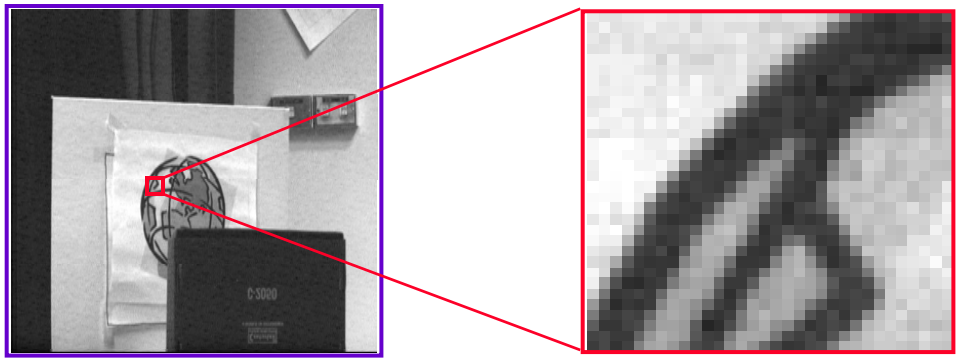


- Unfiltered white-light source for imaging
- Filtered white-light source (Bessel 'R' filter) for flat field tests
- 100 μCi ^{55}Fe source close-coupled for radiation tests
  - *with device front window removed*
- 11 devices tested in one camera
- 10 MHz typical clock rates

Imaging – Dual Serial Readout Effects



Both serial channels at same gain and offset

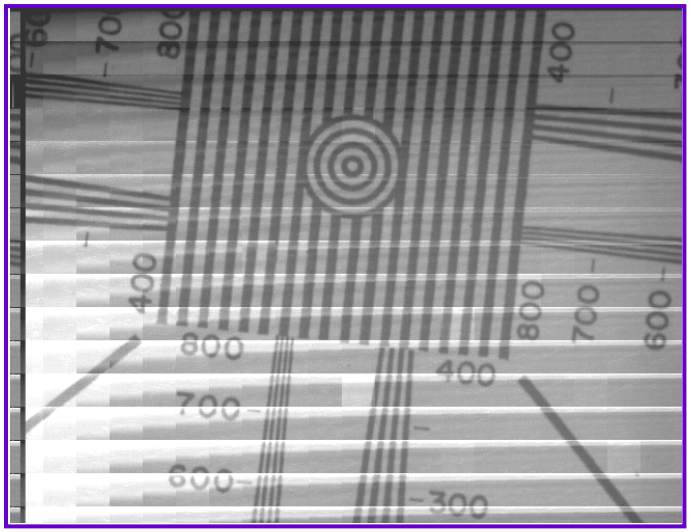


Individual channel gain and offset settings

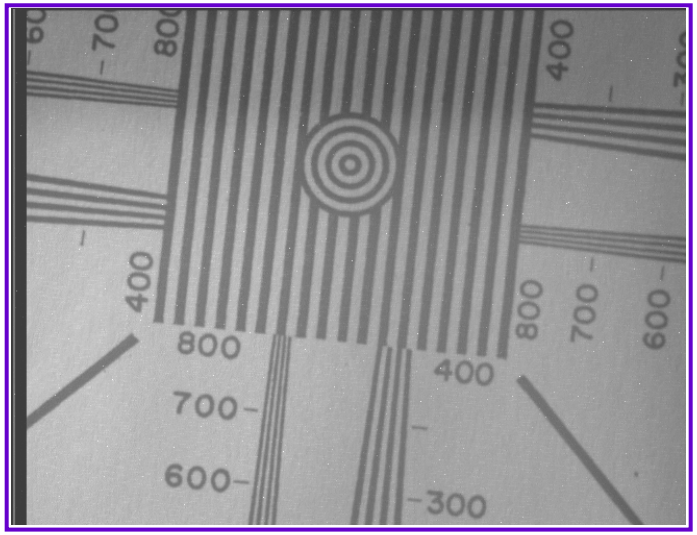
- Dual line readout requires multipoint calibration to set individual serial gains and offsets
- Single line readout used for further device testing

Imaging – ROI Tiling Effects

31x31 Tile Composite



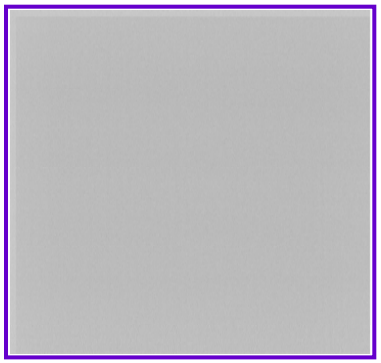
Single Readout Full FOV

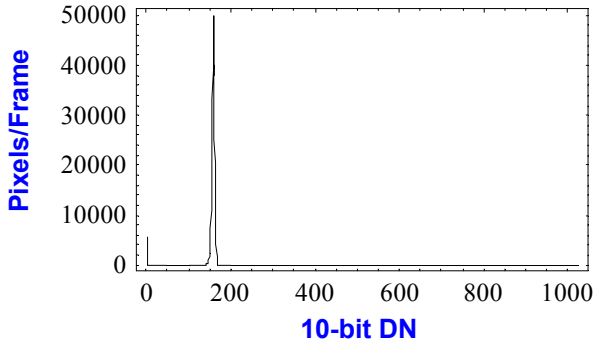


- "tiling" effects observed when building composite image
  - camera and logic specific effects
  - suspect need to shift clock voltages with clock frequency
- full FOV readout used for further characterization

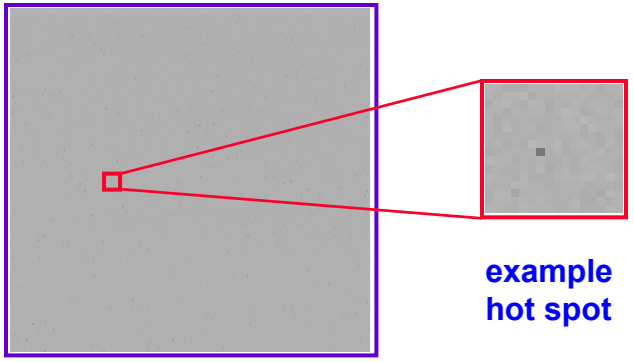
Dark Field

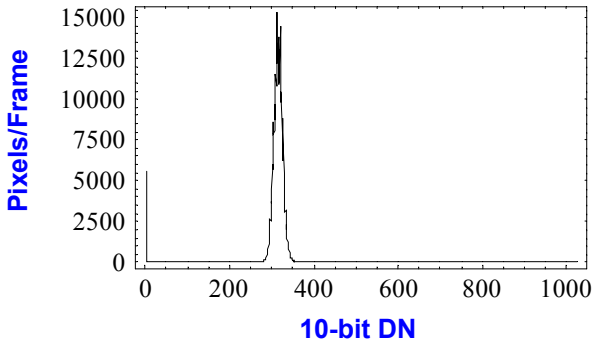
40 ms @ 20 C dark frame (inverted image)





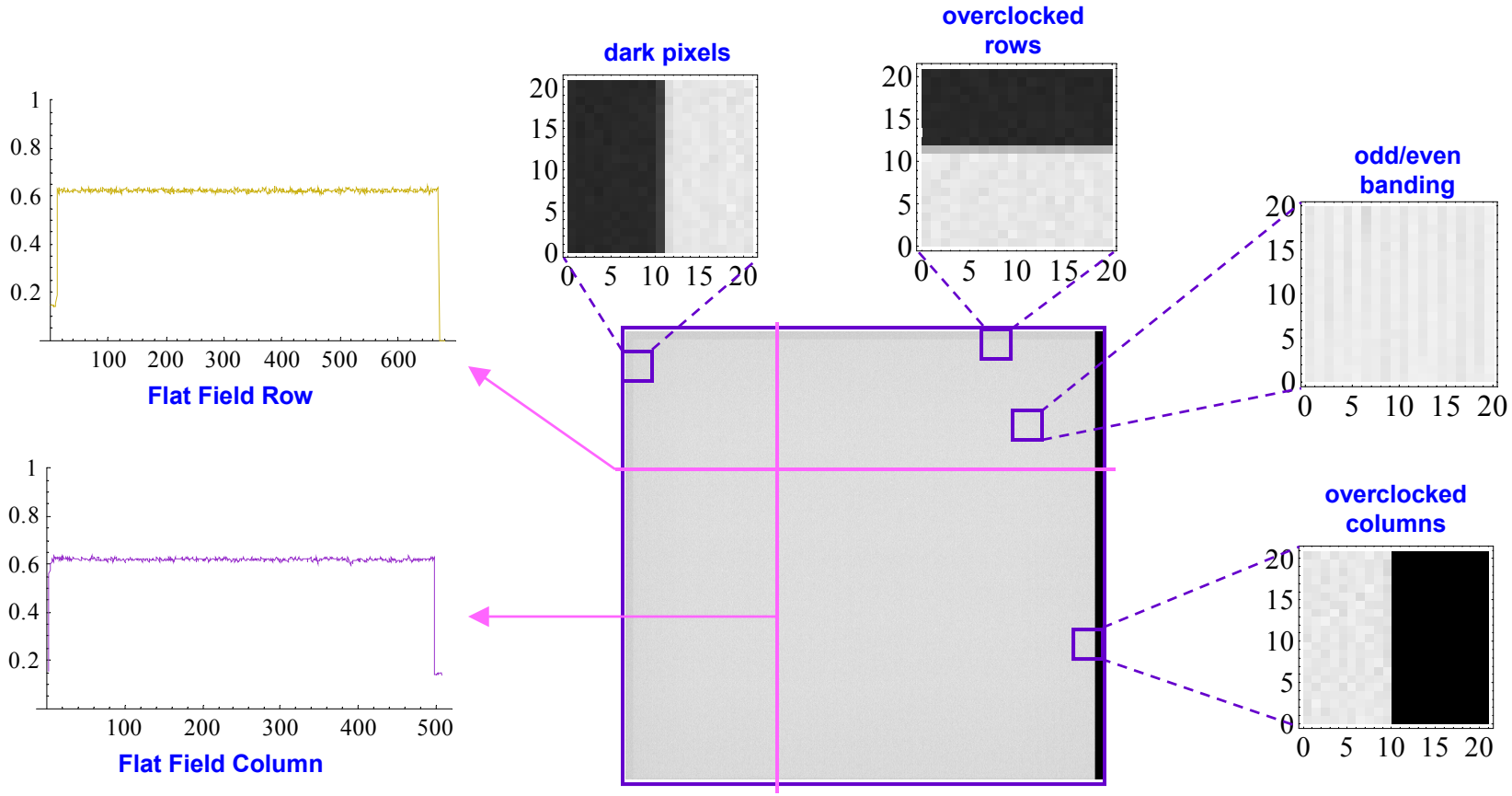
800 ms @ 20 C dark frame (inverted image)





- Reasonable dark current at room temperature
  - about 3700 e- per pixel per second (from later e-/DN slope)
- Numerous "hot" spots (>30)
  - can LP filter for ATP application

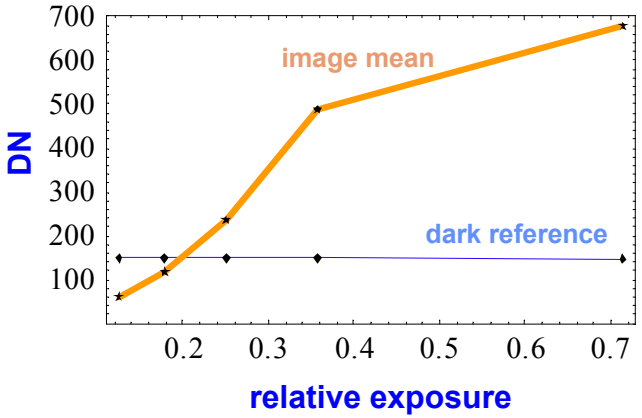
Flat Field



- Bessel 'R' filtered white light source
  - 500–800 nm, peak at 600 nm
- Some odd/even column banding noted near saturation
- Row CTE 0.9995 (from overclocking measurements)
  - 0.998 worst case observed

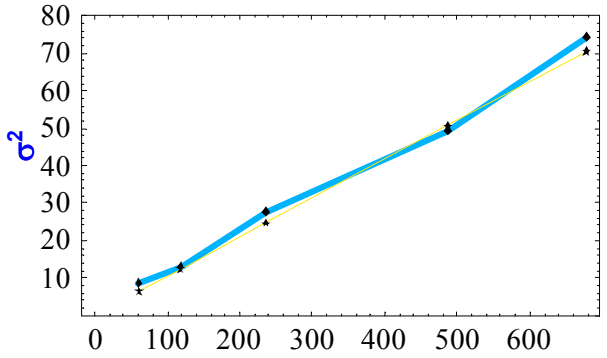
Gain and Saturation Response

Exposure Response
(device #2)

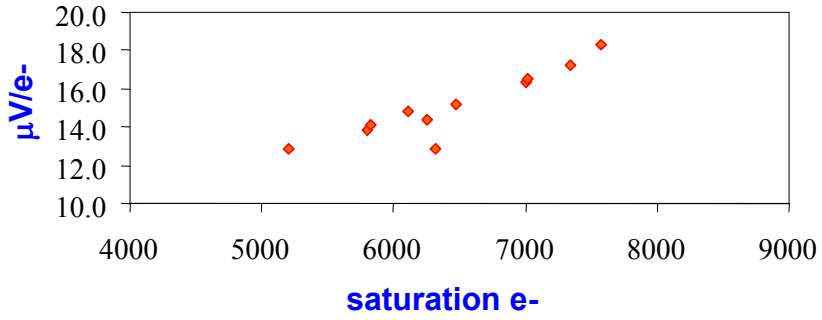


Response Variance
(device #2)

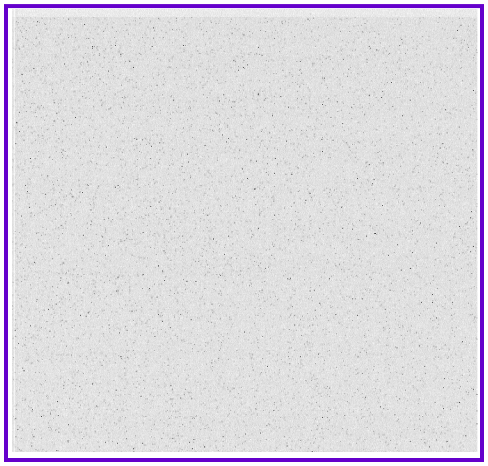
gain from ^{55}Fe histogram
9.6 e-/DN at +23 dB PGA gain



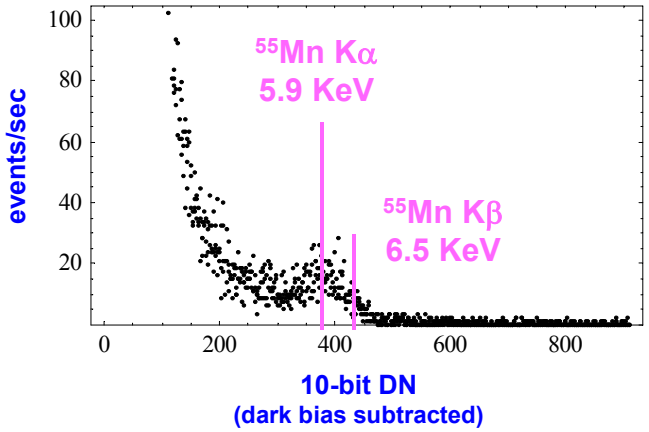
Device Spread



^{55}Fe Testing



^{55}Fe Frame Capture
(inverted image, window removed)



^{55}Fe Event Histogram

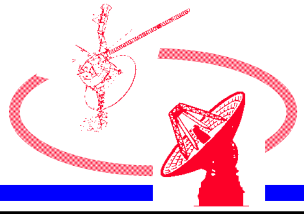
- Removed front window from one device for ^{55}Fe tests
- Histogram derived response of 4.3 e-/DN at +30 dB PGA gain
  - corresponds to 9.6 e-/DN at +23 dB PGA gain
  - 14.4 µV / e- output from TC237 chip

TC237 Camera Performance Summary

Parameter	Typical	Worst Observed	Datasheet
read noise (1σ e-)	26	30	12
full well e-	6500	5000	30000
response, μV/e-	16	13	20
CTE	0.9995	0.998	0.9999
dark current, nA/cm^2	0.4	0.5	0.05
ENOB	8.0	7.4	11.3

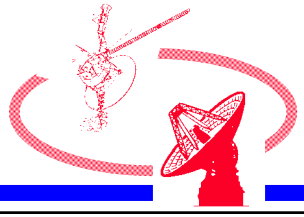
- Low full well and low CTE indicate clock voltage adjustments are required
  - need better rise/fall control for ROI readout
- Dark current higher than datasheet, but not important in this application

Conclusions



- Gain and offset calibration allows use of dual row readout to double peak ROI transfer rate
- Tiling effects limit effective dynamic range of ROI
  - negative impact on ATP spot centroid
  - presently pursuing resolution
- TC237 is a good chip for high frame rate operation
  - Dark current is sufficiently low for this application
  - Further clocking optimization is required

Acknowledgements



The work described was funded by the High Rate Data Delivery Program and performed at the Jet Propulsion Laboratory, California Institute of Technology under contract with the National Aeronautics and Space Administration